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Long-term Variation in Temperature and Dynamic in Venus Upper Atmosphere from ground-based Infrared Heterodyne Spectroscopy

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Abstract

We report on temperatures and wind velocities in the Venusian upper mesosphere/lower thermosphere, deduced from analyzing very high resolution infrared spectroscopic data of CO_2 emission lines acquired between 1990 and 2013.

1. Introduction

The dynamics of the transition zone between the region dominated by sub-solar to anti-solar (SS-AS) flow above 120 km and the superrotation dominated region below 90 km is not yet fully understood. Temperatures in the same region are not very well constrained either. Measurements are essential to gain a global understanding of the atmosphere and to validate global circulation models. Space based observations can only partially provide temperatures and do not offer direct wind measurements at these altitudes [1,2,3 & 4]. Ground-based results still lack in time coverage and spatial resolution. Hence measurements on various time scales and different locations with sufficient spatial resolution on the planet are important. Such observations are carried out with the infrared heterodyne spectrometers THIS from University of Cologne, HIPWAC and IRHS from NASA Goddard space flight center.

2. Instrument and Technique

Infrared heterodyne spectrometers provide a high spectral resolution ($R>10^7$). In addition compared to mm and sub-mm observations a high spatial resolution on the planet is guaranteed. The Instruments can be operated between 7 and 13 μm [5]. Temperatures and winds in planetary atmospheres are retrieved from detection of narrow non-LTE emission lines of CO_2 at 10 μm. These emission lines are induced by solar radiation and occur only in a narrow pressure/altitude region around 110km [6]. Resolving this single molecular features allows retrieval of temperatures and wind velocities. Wind velocities can be determined from the Doppler-shifts of the emission lines with a precision of 10m/s. Temperatures with a precision up to 5K can be calculated from the Doppler-width of the emission lines.

3. Observations and Results

Several observing runs over the last decades were dedicated to collect day-side information from the Venusian upper atmosphere. The individual campaigns are listed in Table 1. Dates are chosen to cover different observing geometries. These observing runs delivered comprehensive data sets to investigate long term temporal variability. The observations were acquired at the NASA Infrared Telescope Facility on Mauna Kea, Hawaii and the McMath Pierce Solar Telescope on Kitt Peak, Arizona.

For example long-term observations of the evening terminator of Venus are shown. Figure 1 shows temperatures in a range between 160 - 260 K. At the equator we found temperatures covering the whole range. The Venusian atmosphere seems to be warmer at low latitudes, 190-260 K. For mid latitudes we determined temperatures between 160-240 K and high latitudes are the coldest part with temperatures between 160-215K. In addition we found that the temperatures for 1990 and 1991 are higher than in 2009, 2011, 2012 and 2013. This could be correlated to the solar-cycle

In Figure 2 long-term observations of the line-of-sight wind velocities at the evening terminator are shown. We found higher wind velocities in 1990, 1992, 2009 and 2012 as in 2011 and 2013. The wind velocities could be correlated to the field-of-view (FOV) on the planet. In the years of higher wind velocities, Venus was large and the FOV small (see. Table. 1). In 2011 and 2013 Venus was smaller and the FOV larger. We will present FOV corrected wind results. The low wind velocities of 2011 and 2013 will increase to the level of the other. After this correction we are able to investigate long-term changes and results will be presented at the conference.

Table 1: Overview of gathered data

date	illu.[%]	size["]	instr.	data[1]
1990 Jan.	7	57	IRHS	W,T
1990 Feb.	11	53	IRHS	W,T
1991 Agu.	6	53	IRHS	W,T
1991 Sept.	8	53	IRHS	W,T
2007 May	54	20	THIS	W
2007 Oct.	50	20	HIPWAC	T
2007 Nov.	64	20	THIS	W
2009 March	5	60	THIS	W,T
2009 April	3	60	THIS	W,T
2009 June	50	24	THIS	W,T
2011 June	96	10	THIS	W,T
2012 March	50	23	THIS	W,T
2012 May	10	51	HIPWAC	W,T
2013 March	100	10	THIS	W,T

[1] W: wind data received, T: temperature data received

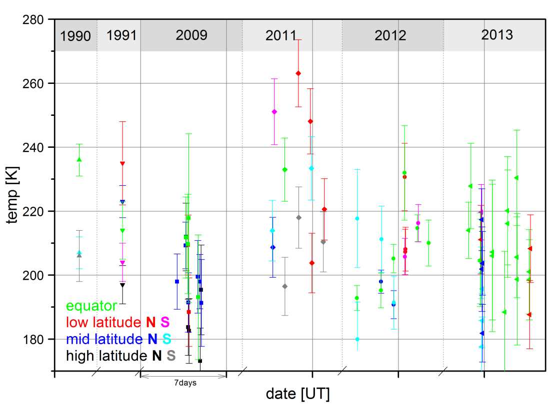

Figure 1: Temperatures at the evening terminator from different observations between 1990 and 2013

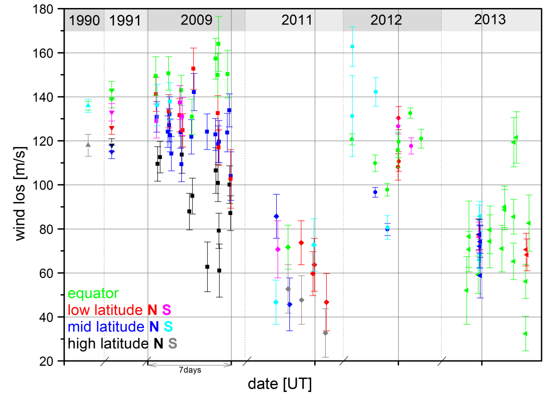

Figure 2: Line-of-sight wind velocities at the evening terminator from different observations between 1990 and 2013

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